PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 013/00617	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/IL 98/00519	International filing date *(day/month/year)* 25/10/1998	(Earliest) Priority Date *(day/month/year)*
Applicant NANOMOTION LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

[X] as suggested by the applicant.

[ ] None of the figures.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/IL 98/00519

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L41/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 712 170 A (NANOMOTION LTD) 15 May 1996 see figure 7	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 1999	23/06/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pelsers, L

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IL 98/00519

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0712170 A	15-05-1996	US 5640063 A	17-06-1997

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
013/00617		
International application No. PCT/IL 98/00519	International filing date (*day/month/year*) 25/10/1998	(Earliest) Priority Date (*day/month/year*)
Applicant NANOMOTION LTD. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

   [X] as suggested by the applicant. [ ] None of the figures.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 98/00519

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L41/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 712 170 A (NANOMOTION LTD) 15 May 1996 see figure 7	1

[ ] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 1999	23/06/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pelsers, L

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

P[illegible]L 98/00519

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0712170 A	15-05-1996	US 5640063 A	17-06-1997

Form PCT/ISA/210 (patent family annex) (July 1992)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To:

FENSTER & COMPANY PATENT
ATTORNEYS, LTD
P.O.Box 10256
Petach Tikva 49002
ISRAEL

RECEIVED
28 -06- 1999
FENSTER & Co.

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (*day/month/year*) 23/06/1999
Applicant's or agent's file reference 013/00617	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IL 98/00519	International filing date (*day/month/year*) 25/10/1998
Applicant NANOMOTION LTD. et al.	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nathalie Desverchere

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international pbulication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

EO/US
PCT/IL98/00519

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing: 04 May 2000 (04.05.00)	
International application No.: PCT/IL98/00519	Applicant's or agent's file reference: 013/00617
International filing date: 25 October 1998 (25.10.98)	Priority date:
Applicant: BEN-YAAKOV, Shmuel	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International preliminary Examining Authority on:

09 August 1999 (09.08.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

Authorized officer:
J. Zahra
Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

FENSTER & COMPANY PATENT
ATTORNEYS, LTD
P.O.Box 10256
Petach Tikva 49002
ISRAEL

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)* 21.09.2000		
Applicant's or agent's file reference 013/00617	**IMPORTANT NOTIFICATION**	
International application No. PCT/IL98/00519	International filing date *(day/month/year)* 25/10/1998	Priority date *(day/month/year)* 25/10/1998
Applicant NANOMOTION LTD. et al.		

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/ European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Magliano, D Tel.+49 89 2399-2245

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 013/00617	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL98/00519	International filing date *(day/month/year)* 25/10/1998	Priority date *(day/month/year)* 25/10/1998
International Patent Classification (IPC) or national classification and IPC H01L41/04		
Applicant NANOMOTION LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☒ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand 09/08/1999	Date of completion of this report 21.09.2000
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Frank, V Telephone No. +49 89 2399 2726

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1,3-15	as originally filed			
2,2a	as received on	01/09/2000	with letter of	30/08/2000

Claims, No.:

1-46	as received on	01/09/2000	with letter of	30/08/2000

Drawings, sheets:

1/7-7/7	as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

see separate sheet

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

☐ restricted the claims.

☒ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	2-6, 8-40, 42-46
	No:	Claims	1, 7, 41
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-46
Industrial applicability (IA)	Yes:	Claims	1-46
	No:	Claims	

2. Citations and explanations

   see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

   see separate sheet

Re Item I
Basis of the report

1. The amendments filed with the letter dated 30/08/00 introduce subject-matter which extends beyond the content of the application as filed, contrary to Article 34(2)(b) PCT. The amendments concerned are the following:

   The specification in claims 7 and 8 that "fewer than four discrete switches are provided". The applicant has not provided any base in the original disclosure for this amendment. In particular, the use of three switches is not disclosed.

   The specification in claim 7 "for controlling at least two directions of displacement" extends beyond the original disclosure, as more than two directions of displacement are not disclosed in the application.

Re Item IV
Lack of unity of invention

1. The separate groups of invention are (reference is made to the originally filed claims):

   1) Claims 1-6, 12-15, 21-39: A micromotor comprising a piezoelectric element on which a common electrode and two groups of other electrodes are formed, a voltage source and two switches for connecting one of said electrode groups to the voltage source.
   2) Claims 7-39: A micromotor comprising an ultrasonically vibrating element, one electrode and an additional electrode formed on said element and a drive circuit, said circuit comprising an oscillating voltage source and a discrete switch arrangement.
   3) Claims 40-45: A method for supplying switchable AC power to a load comprising applying a voltage to the gate of a Mosfet transistor connected between the AC power source and the load.

   They are not so linked as to form a single general inventive concept (Rule 13.1

The statement that the applicant is seeking protection for a circuitry for selecting the direction of displacement of micromotors is not reflected in the scope of this claim. The claim is directed merely to a method for supplying switchable AC power to a load comprising a micromotor. It is clear that the circuits disclosed in D1 are suitable for such an application, although they are clearly not suitable for the application the applicant states in his letter.

The subject-matter of claim 41 is thus not new.

4. The dependent claims do not seem to contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step.

Re Item VIII

Certain observations on the international application

1. The vague and imprecise statement in the description on page 15 implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity (Article 6 PCT) when used to interpret them (see also the PCT Guidelines, III-4.3a).

2. The term "improved" used in claims 1 and 7 is vague and unclear and leaves the reader in doubt as to the meaning of the technical feature to which it refers, thereby rendering the definition of the subject-matter of said claims unclear (Article 6 PCT).

   Furthermore, the use of "improvement" and "wherein said improvement is" renders unclear if the whole micromotor or only said improvement is claimed.

3. Claim 13 is unclear in referring back to claim 7, the discrete switches are only referred to in claim 8.

PCT) for the following reasons:

a) The common features between claims 1 and 7 are the presence of piezoelectric/ultrasonically vibrating element with two electrodes formed on it, a voltage source and a switch. These features are however, already known from the prior art as can be seem form EP-A-0 712 170 (D1) (cf. Fig. 11)-
b) There are no common features between claims 1 and 40, on one hand, and claims 7 and 40, on the other hand, other than the presence of a power source, this is already known (cf. D1, Fig. 7).
c) The technical problem underlying claims 1-39 of changing the drive direction of a micromotor is also known from D1.

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: The Giant Handbook of Electronic Circuits, 1980, pp. 174-177
D2: EP-A-0 712 170

1. The subject-matter of claim 1 is not new having regard to Figure 7 of D1. In fact, according to the applicant electrode 44 is connected to switch 116B and electrode 48 to switch 116D, which switches connect said electrodes to the low voltage battery 112 to cause movement in opposite directions. There are thus at least two switches separately connected according to the characterizing portion of claim 1.

2. The subject-matter of original claim 7 (see Item I above) is not new having regard to the embodiment shown in Fig. 7 of D2.

3. While the applicant's observations concerning the subject-matter of claim 41 have been considered, the previously expressed opinion is nevertheless maintained for the following reasons:

through resonant circuitry attached to each of the elements high side electrodes. The prior art utilizes such multiple inverters to cause directional motion of the piezoelectric motors without any separate switching units. Other prior art devices utilize a single high voltage source and switching circuitry to switch the source between different electrodes. This methodology requires high voltage capable switching circuitry.

A major disadvantage of the prior art drivers is the complexity of the circuitry that is used. For example, a commonly used driver comprises a bridge type inverter circuit (see Fig. 2) that requires six power switches, and two high Q resonant circuits. Other prior art drivers require only one high Q resonant circuit. The reduction in the number of high Q resonant circuits is accomplished by placing the high Q resonant circuit in series with the common electrode. However, six power switches are still used in that prior art device (see EP 0712 170 A1), which application is assigned to the assignee of this application. In Fig. 7 of that device, four switches are used for displacement directional control with two switches for each of the selectable directions. The high Q resonant circuits are sensitive to the accuracy of the circuit component and to the frequency of the applied voltage. As a practical solution for overcoming this sensitively, in the prior art the Q of the drivers was often lowered and the input voltage from the prior art drivers was raised. Extra DC/DC converters were required to enable operation with lower input voltages. Consequently, in the prior art, while the piezoelectric motors are simple the driver circuitry has until now been complex, especially when driving piezoelectric motors in two directions.

SUMMARY OF THE INVENTION

Accordingly, it is an object of some preferred embodiments of the present invention to provide drivers for piezoelectric elements that are reliable, simple and of low cost.

It is an object of some preferred embodiments of the present invention is to provide drivers for piezoelectric elements that operate the piezoelectric elements as actuators or motors bi-directionally with a minimum of components.

It is an object of some preferred embodiments of the invention to provide bi-directional drivers for piezoelectric motors or actuators in which a single high voltage unswitched drive circuit is used for both direction of motion.

It is an object of some preferred embodiments of the present invention to provide bi-directional drivers for piezoelectric motors or actuators in which the direction of motion is changed by switching circuitry located at a low voltage connection of the control circuitry.

It is an object of some preferred embodiments of the present invention to provide drivers for piezoelectric elements that utilize soft switching so as to minimize switching losses

and increase the overall efficiency of the piezoelectric driver unit and to improve electromagnetic compatability.

It is an object of some preferred embodiments of the present invention to provide a piezoelectric driver operated from a low DC voltage source without additional complexity.

CLAIMS

1. An improved micromotor (11) comprising:

a piezoelectric element (12) including a common electrode (17) and a plurality of other electrodes (13, 14) formed thereon and including at least a first and a second electrode group, each group including at least one electrode, wherein the piezoelectric element causes motion in a first direction when a voltage is applied between the first electrode group and a common electrode, and wherein the piezoelectric element causes motion in a second direction when a voltage is applied between the second electrode group and the common electrode;

a voltage source (V_S) that applies voltage to the common electrode; and wherein said improvement is characterized in this that:

at least two switches ($MS1$, $MS2$), separately connected between the first and second electrode groups and a low voltage (43), said switches being operable to selectively connect one of said first and second electrode groups to the low voltage to cause selective motion either in the first or in the second directions.

2. A micromotor according to claim 1 wherein the low voltage is substantially ground.

3. A micromotor according to claim 1 or claim 2 wherein the applied voltage is an AC voltage.

4. A micromotor according to any of the preceding claims wherein the piezoelectric element comprises a rectangular piezoelectric plate having first and second faces wherein the common electrode is formed on the first face and the first and second groups of electrodes are formed on the second face.

5. A micromotor according to claim 4 wherein the first and second groups of electrodes each comprises two electrodes situated in opposite quadrants of the second face.

6. A micromotor according to any of the preceding claims wherein the micromotor comprises a motive surface and wherein motion is induced in a surface of a workpiece pressed against the motive surface when the piezoelectric element is electrified as aforesaid.

7. An improved micromotor (11) comprising:

an ultrasonically vibrating element (12);

a drive circuit comprising:

an oscillating voltage source (V_S) connected to and electrifying at least one electrode (17) of said ultrasonically vibrating element (12) to cause a mechanical displacement of at least a portion thereof; and

said improvement characterized in this that:

fewer than four discrete switches are provided for selectively controlling at least two directions of said displacement.

8. A micromotor according to claim 7 wherein said fewer than four discrete switches are a single discrete switch per direction of said displacement.

9. A micromotor according to either of claims 7 or 8 wherein the ultrasonically vibrating element comprises a piezoelectric element.

10. A micromotor according to any of claim 7-9 wherein:

the at least one additional electrode element comprises a plurality of electrodes (13, 14) applied to a first face of said vibrating element (12); and

the at least one electrode (17) comprises a common electrode applied to a second face of said element.

11. A micromotor according to claim 10 wherein the single discrete switch selectively applies voltage between a first group of said plurality of electrodes (13, 14) and said common electrode (17) to cause displacement in a first direction, said first group including at least one electrode.

12. A micromotor according to claim 11 wherein another single discrete switch selectively applies voltage between a second group of said plurality of electrodes and said common electrode to cause displacement in a second direction, said second group comprising at least one electrode.

13. A micromotor according to any of the preceding claims 7-12 wherein said single discrete switching and said another single discrete switch are each connected to apply voltage

across said element to drive current through said element, and controls for selectively operating either said one or said another single discrete switch to select a direction of said displacement.

14. A micromotor according to any of claims 7-13 wherein said switches are solid state switches.

15. A micromotor according to any of claims 7-13 wherein said switches comprises transistorized switches.

16. A micromotor according to any of claims 7-13 wherein said switches are Mosfet transistors.

17. A micromotor according to claim 12 wherein said discrete switches comprise:

a first Mosfet transistor ($MS1$) connected between a first voltage and said first group of electrodes;

a second Mosfet transistor ($MS2$) connected between said first voltage and said second group of electrodes;

said common electrode being connected to said oscillating voltage source (V_S) and a control that selectively operates said Mosfet transistors to selectively apply said first voltage either to the first electrode group or to said second electrode group.

18. A micromotor according to claim 17 including a source of control voltages (V_{gs1}, V_{gs2}) selectively applied to the gates of said first and second Mosfet transistors for selectively switching said first or said second Mosfet transistors from the non conducting state to the conducting state.

19. A micromotor according to claim 17 or claim 18 and including a pair of diodes (DS_1, DS_2), one of which is across each said Mosfet transistor.

20. A micromotor according to claim 19 wherein the diodes are connected such that they conduct DC current toward the micromotor.

21. A micromotor according to any of claims 17-20 wherein, when the transistor is off, one end of the Mosfet is at a DC voltage equal to the peak of the oscillating voltage and the oscillating voltage is impressed across the Mosfet transistor, such that the voltage across the transistor is substantially unipolar.

22. A micromotor according to any of the preceding claims 7-21 wherein said voltage source comprises an inverter.

23. A micromotor according to claim 22 wherein the inverter is a forward-flyback inverter.

24. A micromotor according to claim 23 wherein said forward-flyback inverter comprises:

a magnetic element (53) having a primary winding (58) and a secondary winding (60), said primary winding being connected between a first inverter voltage and one side of an inverter operating switch, the other side of said inverter operating switch connected to a second inverter voltage so that when said inverter operating switch is in the conductive stage, current flows through said primary and when said inverter opening switch is in a non conductive state substantially no current flows through said primary; and

a control voltage source (Vgs) which selectively turns said inverter operating switch on or off, the secondary of said magnetic element being connected to said common electrode for applying oscillating voltage thereto.

25. A micromotor according to claim 24 wherein said inverter operating switches are solid state switches.

26. A micromotor according to claim 24 wherein said inverter operating switches are transistorized switches.

27. A micromotor according to claim 24 wherein said inverter operating switches are Mosfet transistors, and comprising:

circuitry that causes said inverter output to resonate at substantially the mechanical resonant frequency of said piezoelectric element.

28. A micromotor according to claim 27 wherein said circuitry that causes said inverter output to resonate at substantially the mechanical resonant frequency of the piezoelectric comprises a capacitor (C_r)bridging said switch (51) and in series with the primary (58) of the magnetic element, said capacitor operating in conjunction with the capacitance of said piezoelectric element to cause said magnetic element (53) to resonate at substantially the mechanical resonant frequency of the micromotor.

29. A micromotor according to claim 22 wherein said inverter is a push-pull inverter.

30. A micromotor according to claim 29 wherein said push-pull inverter comprises a transformer (TR) having a primary (66) and a secondary ($N1$) ;

a series inductor (LSP) connecting a first inverter input to a mid part of the primary (66) of said transformer,

the secondary ($N1$)of said transformer connected to said common electrode;

one side of the primary of said transformer being connected through a first push-pull inverter switch (Q_{p1})to a second inverter input (69); and

the other side of said primary of said transformer being connected through a second push-pull inverter switch Q_{p2} to said second inverter input (69).

31. A micromotor according to claim 30 wherein said first and second push-pull inverter switches are solid states switches.

32. A micromotor according to claim 31 wherein said first and second push-pull inverter switches are transistorized switches.

33. A micromotor according to claim 31 wherein said first and second push-pull inverter switches are Mosfet type switches.

34. A micromotor according to any of claims 30-32 wherein the capacitance of said piezoelectric element and the inductances of the series inductance and of said transformer match the electrical circuit to the mechanical resonance of said piezoelectric element.

35. A micromotor according to claim 34 wherein the first and the second push-pull inverter switches are each selectively operated by control voltages.

36. A micromotor according to claim 35 wherein the control voltages are square wave voltages.

37. A micromotor according to any of claims 30-36 wherein said push-pull inverter includes a buck section for controlling the amplitude of the voltage connected to said primary of said transformer.

38. A micromotor according to claim 37 wherein said buck section includes:

a series buck section switch (Qbuck);

a diode (Dbuck) connected between an output of the buck section switch and said second input of the inverter; and

a control voltage (Dow) operative to cause the buck section switch to conduct.

39. A micromotor according to any of claims 30-38 wherein the second input is ground.

40. A micromotor according to any of claims 30-39 wherein the first invert input is electrified with a DC voltage.

41. A method of supplying switchable AC power to a load comprising a micromotor (11), said method comprising:

connecting a first terminal of an AC power source (V_S) to one side of the load;

connecting the drain (42) of a Mosfet transistor to a second terminal (43) of the AC power source;

connecting the source (41) of the Mosfet transistor to the other side of the micromotor; and

selectively supplying power to the load by applying a voltage between a gate of the Mosfet transistor and the second AC terminal (43).

42. A method according to claim 41 and including a diode ($DS1$ or $DS2$) across the Mosfet transistor.

43. A method according to claim 42 wherein the diode is connected such that it conducts current between the second terminal (43) and the other side of the load.

44. A method according to any of claims 41-43 and including placing a capacitor (C_S)in series with the load.

45. A method according to claim 44 wherein the load does not comprise a DC blocking capacitor.

46. A method according to any of claims 41-45 wherein, when the transistor is off, one end of the Mosfet is at a DC voltage equal to the peak voltage of the AC source and AC voltage of the AC source is impressed across the Mosfet transistor, such that the voltage across transistor is substantially unipolar.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification [6] :
H01L 41/04

A1

(11) International Publication Number: WO 00/25368

(43) International Publication Date: 4 May 2000 (04.05.00)

(21) International Application Number: PCT/IL98/00519

(22) International Filing Date: 25 October 1998 (25.10.98)

(71) Applicant *(for all designated States except US)*: NANOMOTION LTD. [IL/IL]; P.O. Box 223, 20692 Yoqne'am (IL).

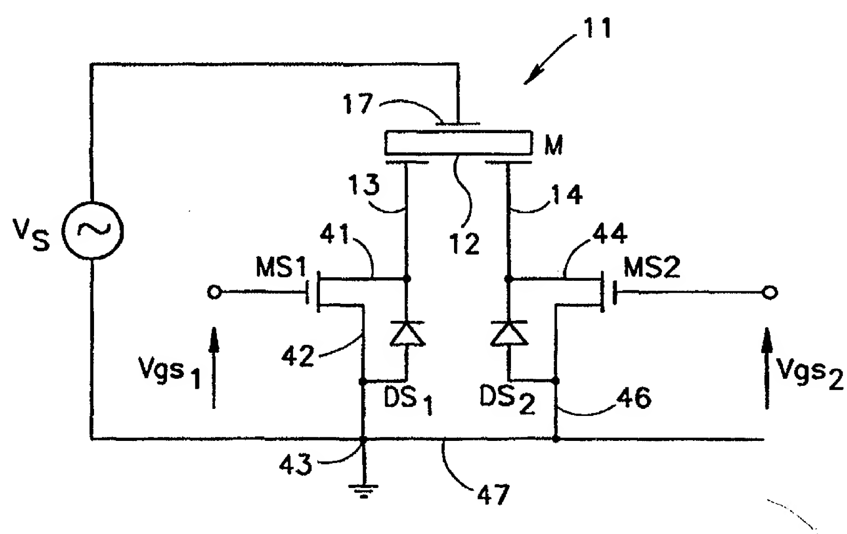
(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: BEN-YAAKOV, Shmuel [IL/IL]; Reuven Hecht Street 57, 84236 Beer-Sheva (IL).

(74) Agents: FENSTER, Paul et al.; Fenster & Company Patent Attorneys, Ltd, P.O. Box 10256, Petach Tikva 49002 (IL).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: DRIVER FOR PIEZOELECTRIC MOTORS



(57) Abstract

A micromotor comprising: a piezoelectric element including a common electrode and a plurality of other electrodes formed thereon and including at least a first and a second electrode group, each group including at least one electrode, wherein the piezoelectric element causes motion in a first direction when a voltage is applied between the first electrode group and the common electrode, and wherein the piezoelectric element causes motion in a second direction when a voltage is applied between the second electrode group and the common electrode; a voltage source that electrifies the common electrode; and at least two switches separately connected between the first and second electrode groups and a low voltage, said switches being activatable to connect one of said first and second electrode groups to the low voltage to cause selective motion in the first or second directions.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01L 41/04	A1	(11) International Publication Number:	WO 00/25368
		(43) International Publication Date:	4 May 2000 (04.05.00)

(21) International Application Number: PCT/IL98/00519

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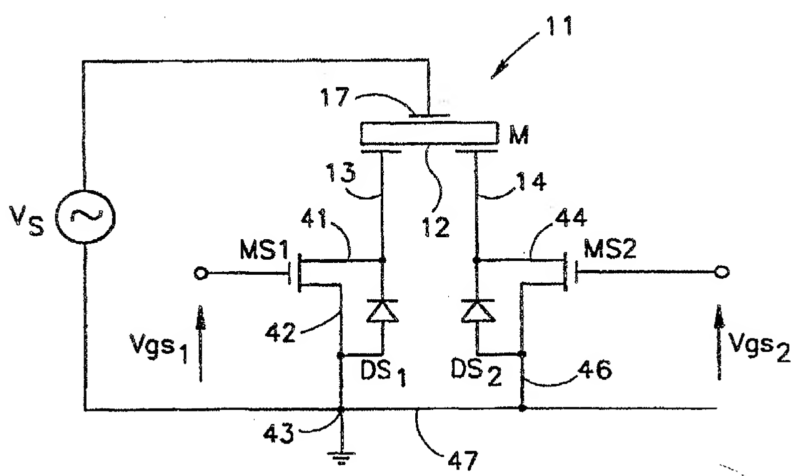
Published
With international search report.

(54) Title: DRIVER FOR PIEZOELECTRIC MOTORS



(57) Abstract

A micromotor comprising: a piezoelectric element including a common electrode and a plurality of other electrodes formed thereon and including at least a first and a second electrode group, each group including at least one electrode, wherein the piezoelectric element causes motion in a first direction when a voltage is applied between the first electrode group and the common electrode, and wherein the piezoelectric element causes motion in a second direction when a voltage is applied between the second electrode group and the common electrode; a voltage source that electrifies the common electrode; and at least two switches separately connected between the first and second electrode groups and a low voltage, said switches being activatable to connect one of said first and second electrode groups to the low voltage to cause selective motion in the first or second directions.

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DRIVER FOR PIEZOELECTRIC MOTORS

FIELD OF THE INVENTION

The present invention relates to systems for driving piezoelectric actuators and piezoelectric motors and more particularly to the electronic circuitry of such drivers.

BACKGROUND OF THE INVENTION

Piezoelectric materials are characterized in that when they are subjected to electrical fields they can be made to deflect; i.e., produce mechanical motion. Also when mechanical stress is applied to piezoelectric elements so that they undergo displacement they generate electrical signals. These characteristics are the reason that piezoelectric materials are useful in applications ranging from sensors to mechanical motors. Examples of piezoelectric elements being used as motors is shown for example in US patents 5,714,833 and 5,777,423; which patents are assigned to the assignee of the invention of this application. Piezoelectric motors are characterized by their mechanical simplicity. They have very few parts, no separate moving parts, and there are no critical mechanical components such as gears, shafts, bearings etc. Consequently, piezoelectric motors are relatively inexpensive and highly reliable.

A piezoelectric element represents an electrical reactive load (mainly capacative) that requires an AC signal of substantial voltage amplitude to cause the mechanical displacement. The required voltage amplitude is generally in the range of a few hundred volts (RMS). For effectively operating the piezoelectric element as a motor or actuator a drive circuit applies voltage thereto of a specific frequency with low harmonic distortion. For the best results, i.e. maximum displacement, the specific frequency should equal the mechanical resonant frequency of the piezoelectric element. A simplified circuit that could be used to drive a piezoelectric motor is shown in Fig. 1A, while such a motor is illustrated in Fig. 1B. This method required two sources and two matching (high-Q) resonant circuits (not shown).

A preferred manner of actuating bidirectional operation of the piezoelectric element provides one side of the element with a pair of electrodes that are connected to a voltage source, such as a switch mode inverter. An opposite side of the piezoelectric element has a single common electrode. The common electrode is grounded or connected to ground by passive or active elements so that current from each of the pair of electrodes flows in opposite directions to cause bidirectional displacement of the piezoelectric element.

The drive circuits for piezoelectric motors basically provide AC voltages to the electrodes according to the directional movement required or desired. Typical prior art drive circuits for actuating the piezoelectric elements to provide movement in a selected direction or selected directions comprise separate inverter circuits coupled to the piezoelectric element

through resonant circuitry attached to each of the elements high side electrodes. The prior art utilizes such multiple inverters to cause directional motion of the piezoelectric motors without any separate switching units. Other prior art devices utilize a single high voltage source and switching circuitry to switch the source between different electrodes. This methodology requires high voltage capable switching circuitry.

A major disadvantage of the prior art drivers is the complexity of the circuitry that is used. For example, a commonly used driver comprises a bridge type inverter circuit (see Fig. 2) that requires six power switches, and two high Q resonant circuits. The high Q resonant circuits are sensitive to the accuracy of the circuit component and to the frequency of the applied voltage. As a practical solution for overcoming this sensitively, in the prior art the Q of the drivers was often lowered and the input voltage from the prior art drivers was raised. Extra DC/DC converters were required to enable operation with lower input voltages. Consequently, in the prior art, while the piezoelectric motors are simple the driver circuitry has until now been complex, especially when driving piezoelectric motors in two directions.

SUMMARY OF THE INVENTION

Accordingly, it is an object of some preferred embodiments of the present invention to provide drivers for piezoelectric elements that are reliable, simple and of low cost.

It is an object of some preferred embodiments of the present invention is to provide drivers for piezoelectric elements that operate the piezoelectric elements as actuators or motors bi-directionally with a minimum of components.

It is an object of some preferred embodiments of the invention to provide bi-directional drivers for piezoelectric motors or actuators in which a single high voltage unswitched drive circuit is used for both direction of motion.

It is an object of some preferred embodiments of the present invention to provide bi-directional drivers for piezoelectric motors or actuators in which the direction of motion is changed by switching circuitry located at a low voltage connection of the control circuitry.

It is an object of some preferred embodiments of the present invention to provide drivers for piezoelectric elements that utilize soft switching so as to minimize switching losses and increase the overall efficiency of the piezoelectric driver unit and to improve electromagnetic compatability.

It is an object of some preferred embodiments of the present invention to provide a piezoelectric driver operated from a low DC voltage source without additional complexity.

It is an object of some preferred embodiments of the present invention to provide a discrete bidirectional switching circuit used in conjunction with an AC voltage provided for operating a piezoelectric motor or other AC load.

Some prior art driver circuits for driving piezoelectric motor from a DC voltage source, integrally, combined switching and inverter circuitry. That is the inverters did the switching of the inverter output to the piezoelectric element's electrodes without any discrete switching circuitry. The present invention separates the inverter and switching portions of the driver circuitry by providing discrete switching circuitry. Surprisingly, the result is a circuit for driving the piezoelectric element bidirectionally of decreased complexity using fewer components and operating more reliably.

In accordance with one aspect of the invention, a driver circuit for driving a piezoelectric type motor comprises an inverter circuit for providing an oscillating voltage to cause a mechanical displacement of a piezoelectric element and a separate switching arrangement for selecting the direction of said displacement. The driver circuit in the invention of this application delivers the driving voltages to the piezoelectric element at the mechanical resonant frequency of said piezoelectric element.

In a preferred embodiment of the invention a discrete switch arrangement includes high frequency switches for selectively applying voltages across said piezoelectric element to cause mechanical displacement of the piezoelectric element in a selected direction or selected directions. In preferred embodiments of the invention, the switches are on a low voltage side of the connection to the piezoelectric element.

There is thus provided, in accordance with a preferred embodiment of the invention, a micromotor comprising:

a piezoelectric element including a common electrode and a plurality of other electrodes formed thereon and including at least a first and a second electrode group, each group including at least one electrode, wherein the piezoelectric element causes motion in a first direction when a voltage is applied between the first electrode group and the common electrode and wherein the piezoelectric element causes motion in a second direction when a voltage is applied between the second electrode group and the common electrode;

an voltage source that electrifies the common electrode; and

at least two switches separately connected between the first and second electrode groups and a low voltage, said switches being activatable to connect one of said first and second electrode groups to the low voltage to cause selective motion in the first or second directions.

Preferably, the low voltage is substantially ground. Preferably, the applied voltage is an AC voltage.

In a preferred embodiment of the invention, where the piezoelectric element comprises a rectangular piezoelectric plate having first and second faces, the common electrode is formed on the first face and the first and second groups of electrodes are formed on the second face. Preferably, the first and second groups of electrodes each comprises two electrodes situated in opposite quadrants of the second face.

Preferably, the micromotor comprises a motive surface and motion is induced in a surface of a workpiece pressed against the motive surface when the piezoelectric element is electrified as aforesaid.

There is further provided, in accordance with a preferred embodiment of the invention, a micromotor comprising:

an ultrasonically vibrating element; and

a drive circuit comprising:

an oscillating voltage source connected to and electrifying at least one electrode of said ultrasonically vibrating element to cause a mechanical displacement of a portion thereof; and

a discrete switch arrangement attached to at least one additional electrode of said ultrasonically vibrating element to which said oscillating voltage is not connected which switch arrangement selects the direction of said displacement.

Preferably, the ultrasonically vibrating element comprises a piezoelectric element.

Preferably, the at least one additional electrode comprises a plurality of electrodes applied to a first face of said vibrating element; and the at least one electrode comprises a common electrode applied to a second face of said element. Preferably, the discrete switch arrangement selectively applies voltage between a first group of said plurality of electrodes and said common electrode to cause displacement in a first direction, said first group including at least one electrode. Preferably, the discrete switch arrangement selectively applies voltage between a second group of said plurality of electrodes and said common electrode to cause displacement in a second direction, said second group comprising at least one electrode.

In a preferred embodiment of the invention, the discrete switching arrangement comprises a pair of switches connected to apply voltages across said element to drive current through said element, and controls for selectively operating said switches to select the direction of said displacement. Preferably, the switches of said discrete switching arrangement

comprise solid state switches, preferably, transistorized switches and most preferably, Mosfet transistors.

In a preferred embodiment of the invention, the discrete switch arrangement comprises:

a first Mosfet connected between a first voltage and said first group of electrodes;

a second Mosfet connected between said first voltage and said second group of electrodes, said common electrode being connected to a second voltage, and

a control that selectively operates said Mosfet switches to selectively apply said first voltage to the first electrode group or to said second electrode group.

Preferably, the micromotor includes a source of control voltages selectively applied to the gates of said first and second Mosfet transistors for selectively switching said first or said second Mosfet transistors from the non conducting state to the conducting state.

Preferably, the micromotor includes a pair of diodes, one of which is connected across each said Mosfet transistor. Preferably, the diodes are connected such that they conduct DC current toward the micromotor.

In a preferred embodiment of the invention, the transistor is off, one end of the Mosfet is at a DC voltage equal to the peak of the oscillating voltage and the oscillating voltage is impressed across the Mosfet transistor, such that the voltage across transistor is substantially unipolar.

In a preferred embodiment of the invention, the source comprises an inverter, preferably, a forward-flyback inverter.

Preferably, the forward-flyback inverter comprises:

a magnetic element having a primary winding and a secondary winding, said primary winding being connected between a first inverter voltage and one side of an inverter operating switch, the other side of said inverter operating switch connected to a second inverter voltage so that when said inverter operating switch is in the conductive stage, current flows through said primary and when said inverter operates switch is in a non conductive state substantially no current flows through said primary; and

a control voltage source which selectively turns said inverter operating switches switch on or off, the secondary of said magnetic element being connected to said discrete switching arrangement.

Preferably, the inverter operating switches comprise solid state switches, preferably transistorized switches, most preferably, Mosfet transistor, and further comprises circuitry that

causes said inverter output to resonate at substantially the mechanical resonant frequency of said piezoelectric element.

In a preferred embodiment of the invention, the circuitry that causes said inverter output to resonate at substantially the mechanical resonant frequency of the piezoelectric comprises a capacitor bridging said switch and in series with the primary of the magnetic element, said capacitor operating in conjunction with the capacitance of said ultrasonically vibrating motor to turn said magnetic element to resonate at substantially the mechanical resonant frequency of the motor.

In a preferred embodiment of the invention, the inverter is a push-pull inverter.

Preferably, the push-pull inverter comprises a transformer, having a primary and a secondary;

a series inductor connecting a first inverter input to a mid part of the primary of said transformer,

the secondary of said transformer connected to said discrete switching arrangement and one side of the primary of said transformer being connected through a first push-pull inverter switch to a second inverter input,

the other side of said primary of said transformer being connected through a second push-pull inverter switch to said second input.

Preferably, the first and second push-pull switches comprise solid states switches, more preferably, transistorized switches and most preferably, Mosfet type switches.

In a preferred embodiment of the invention, the capacitance of said ultrasonic motor and the inductances of the series inductance and of said transformer match the electrical circuit to the mechanical resonance of said piezoelectric element. Preferably, the first or the second push-pull inverter switches are each selectively operated by control voltages, preferably, square wave voltages.

In a preferred embodiment of the invention, the push-pull inverter includes a buck section for controlling the amplitude of the voltage connected to said primary of said transformer. Preferably, the buck section includes:

a series buck section switch connected between the first input of the inverter and the series inductor;

a diode connected between an output of the buck section switch and said second input of the inverter and,

a control voltage operative to cause the buck section switch to conduct.

In a preferred embodiment of the invention, the second input is ground. Preferably, the first input is electrified with a DC voltage.

There is further provided, in accordance with a preferred embodiment of the invention, a method of supplying switchable AC power to a load comprising:

connecting a first terminal of an AC power source to one side of the load;

connected a Mosfet transistor between a second terminal of the AC power source and the other side of the load; and

selectively supplying power to the load by applying a voltage between a gate of the Mosfet and the second AC terminal.

Preferably a diode is connected across the Mosfet. Preferably, the diode is connected such that it conducts current between the second terminal and the other side of the load.

In a preferred embodiment of the invention a capacitor is placed in series with the load, which preferably, does not include a DC blocking capacitor.

In accordance with a preferred embodiment of the invention, when the transistor is off, one end of the Mosfet is at a DC voltage equal to the peak voltage of the AC source and AC voltage of the AC source is impressed across the Mosfet transistor, such that the voltage across transistor is substantially unipolar.

BRIEF DESCRIPTION OF THE DRAWINGS

The above named and other features and objects of the present invention will be best understood from the following description of preferred embodiments of the invention taken in conjunction with the accompanying drawings, in which:

Figs. 1A and 1B are a simplified schematic showing of a bi-directional piezoelectric motor and associated driver circuitry of the prior art;

Fig. 2 is prior art bridge circuit implementation of a bi-directional piezoelectric motor driver;

Fig. 3 is a basic electrical component schematic showing of an AC switch operating a piezoelectric motor;

Fig. 4 is a schematic showing of a discrete bi-directional switch used with a piezoelectric motor;

Fig. 5 is a schematic showing of a preferred driver circuit comprising a forward-flyback inverter used in conjunction with the bi-directional switch for operating the piezoelectric motor;

Fig. 6 is an equivalent circuit of Fig 5 showing elements of the secondary circuitry reflected to the primary;

Fig. 7 is the schematic showing of the circuit of Fig 6 when the switch Qff is conducting;

Fig 8 is a schematic showing of the circuit of Fig 6 when the switch Q_{ff} is non-conducting;

Fig 9 is a schematic showing of a preferred driver circuit comprising a push-pull parallel resonant inverter used in conjunction with the bi-directional switch for operating the piezoelectric motor;

Fig. 10 is a schematic showing of the push-pull inverter of Fig 9 including a buck section providing output voltage control; and

Fig 11 is a showing of the voltage wave form at point A of Fig. 10.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figs. 1A and 1B are a simplified schematic showing of a bi-directional piezoelectric motor as used in the prior art to aid in understanding the invention. The piezoelectric motor 11, comprises a piezoelectric crystal or ceramic element 12, that operates responsive to electric voltage thereacross to provide mechanical displacement.

As shown in Figs. 1A and 1B, to operate the motor bi-directionally, two pairs of electrodes 13 and 14 are attached to a first face 16 of element 12 and a common electrode 17 is attached to and covers substantially all of an opposite face 18 of element 12. Common electrode 17 is grounded at 19. A first AC voltage V1 is applied between electrodes 14 and 17 by the operation of switch SW1 responsive to a control signal S1. Voltage V1 causes mechanical displacement of a surface pressed against an extension 9 of element 12 in a first direction.

Operation of switch SW2, responsive to a control signal S2, applies a second AC voltage V2 between electrodes 13 and 17. Voltage V2 causes mechanical displacement of a surface pressed against extension 9 in a second direction. The piezoelectric element 12 is reactive in nature and mechanically resonates at particular frequencies in transverse directions.

It should be understood that when electrodes are shown, in the following drawings, in the manner of electrodes 13 and 14, what is meant is a configuration such as that shown in Fig. 1B.

Fig. 2 shows a typical prior art implementation of a bi-directional driver for a piezoelectric motor. A prior art bi-directional inverter driver as shown in Fig. 2 has a positive supply voltage Vin applied to conductor 21. A switch shown as Q1 is connected to conductor 21. The switch is shown as a Mosfet type transistor with the source 22 connected to the conductor 21. The switch Q1 in the preferred embodiment is operated to the conducting state

by a pulsed gate control signal S1 applied to gate DR1. Responsive to the gate control signals the switch Q1 applies DC voltage Vin as pulses to the drain 23 of switch Q1. The drain 23 is connected to conductor 24 which connects to common electrode 17 of piezoelectric motor 11. Conductor 24 is connected to ground through switch Q2 operated to the conducting condition in response the pulsed control signal S2 applied on the gate DR2 of switch Q2. The source 26 of switch Q2 is connected to conductor 24 and the drain 27 of switch Q2 is connected to ground 28 through conductor 29.

Electrodes 14 of piezoelectric motor 11 is connected to the junction of a capacitor C1 and an inductor L1. Capacitor C1 and inductor L1 form a resonant circuit tuned to the mechanical resonance frequency of the piezoelectric motor. The other side of capacitor C1 is connected to conductor 24. The other side of inductor L1 is connected through conductor 30 to the junction of another pair of switches, Q5 and Q6. Transistor switches Q5 and Q6 operate to the conductive state responsive to pulsed signals S5 and S6 on the gate drivers shown as DR5 and DR6. The source 31 of switch Q5 is coupled to the DC voltage Vin on conductor 21. The drain 32 of switch Q5 is coupled to the source 33 of switch Q6. The drain 34 of switch Q6 is coupled is to ground conductor 29.

Another half bridge circuit connects electrodes 13 of the motor 11 to source voltage Vin. More particularly, the electrode 13 of the motor 11 is connected to the junction of inductor L2 and capacitor C2 which form a second resonant circuit. The other side of capacitor C2 is connected to conductor 24. The other side of inductor L2 is connected to the junction of the drain 36 of switch Q3 and the source 37 of switch Q4. The source 38 of switch Q3 is coupled to the DC voltage Vin on conductor 21. The drain 39 of switch Q4 is coupled to the grounded conductor 29. The switches Q2, Q4 are operated responsive to signals S3, S4.

In operation, Q1 and Q2 act together with either Q3 and Q4 or Q5 and Q6 to apply an oscillating voltage to the resonant circuit of L1/C1 or L2/C2 respectively, in a manner well known in the art. Depending on which half bridge is operated together with Q1/Q2, either electrodes 13 or 14 will be energized. This allows for reversible motion of a surface pressed against extension 9.

In greater detail when switches Q1, Q2 and Q5, Q6 are operated, an AC voltage is applied between electrodes 14 and 17 of the motor 11 at the resonant frequency set by capacitor C1 and inductor L1. Alternatively, an AC voltage is applied between electrodes 13 and 17 by the operation of switches Q1, Q2 and Q3, Q4. This applies an AC voltage across electrodes 13 and 17 at the resonant frequency set by inductor L2 and capacitor C2. Thus, the voltage across electrodes 13 and 17 responsive to the operation of switches Q1- Q4 cause the

motor to operate in one direction and the operation of switches Q1, Q2 and Q5, Q6 cause the motor to operate in the opposite direction. This typical prior art circuitry requires two high Q resonant circuits, C1, L1 and C2, L2 and six switching components operated responsive to signals S1-S6 applied to the gates DR1-DR6.

A high voltage Vin is needed across the motor if reasonable Q factors are to be used. For example, a Q factor of 5 requires the input voltage to be about 1/5 of the required motor voltage. A motor voltage of 400 volts is reasonable. This implies that the input voltage needs to be 80 volts. If lower voltages are required then additional circuitry would have to be added.

Fig. 3 shows an AC switch and equivalent circuit of the piezoelectric device, respectively, useful in understanding preferred embodiments of the invention.

In Fig. 3, L_S/C_S represent the mechanical resonance of the piezoelectric device, R_S represents mechanical work and losses and C_p is the electrode capacitance. Since C_p is very large, an inductor is usually added in series with the piezoelectric device.

When switch SWL is closed, V_s is applied to the piezoelectric device and the motor operates. When SWL is open, capacitor C_p is clamped to the peak value of Vs via diode D_S. This DC voltage is maintained so long as SWL is open. In this situation, (DC voltage across the piezoelectric element) the motor does not operate. AC Voltage appears across the diode.

Fig. 4 shows a preferred embodiment of the discrete bidirectional AC switch for operating with an AC voltage V_s to drive piezoelectric motor 11. As in Fig. 1, piezoelectric motor 11 comprises electrodes 13, 14 on one face and electrode 17 on the opposite face of piezoelectric element 12. While any solid state switching units can be used, in a preferred embodiment there two Mosfet switches M_{S1} and M_{S2}, each connected to electrodes 13 and 14 respectively are used as the switches. Diodes D_{S1} and D_{S2} shown as connected across the switches M_{S1} and M_{S2} are inherent in Mosfet transistors. Source 41 of switch M_{S1} and diode D_{S1} are both connected to electrodes 13 of motor 11. Drain 42 of switch M_{S1} and the other side of diode D_{S1} are shown as being grounded at 43. Source 44 of switch M_{S2} is connected to the anode of diode D_{S2} and to electrodes 14. Drain 46 of switch M_{S2} is connected ground 43 through conductor 47. One side of the alternating voltage source is connected to the common electrode 17 of the piezoelectric motor 11 while the other side of the voltage source is coupled to ground through conductor 47. The operating direction of the piezoelectric motor 11 is controlled by gate voltages V_{gs1} and V_{gs2} applied to the gates of switches M_{S1} and M_{S2} respectively. When M_{S1} is closed (and M_{S2} is open), the AC voltage is applied between electrodes 17 and 13 and a surface pressed against extension 9 moves in a first direction. When M_{S2} is closed an M_{S1} is open, travel is in the reverse direction.

This is facilitated by the fact that when M_{S2} is open, it disconnects the AC current path (the AC voltage appears across the switch) from electrode 14. The DC voltage that develops, under these conditions, between electrodes 14 and 17 does not interfere with the operation of the motor, as effected by the AC voltage between electrodes 17 and 13.

Major advantages of this bidirectional switching configuration is that:

a) the control voltages are all referred to ground, and

b) only one AC source is required.

One reason these advantages are available is that unlike the prior art drivers, the common electrode is not referenced to ground, Rather, one of the electrode pairs 13 or 14 is grounded. This allows for a single power source to feed the common electrode and, since the individual electrodes are near ground, for the switching to be controlled with low voltages.

This switching scheme can be incorporated in conjunction with any inverter driver but it has special merits when the inverter configuration of this invention is used to provide the driving voltage V_S.

A preferred embodiment of the AC source is a forward-flyback type inverter such as schematically shown in Fig. 5. Therein a high frequency switch such as Mosfet transistor Q_{ff} 51 is driven by square wave signal V_{sg} applied to the gate electrode 52. Source 54 of switch Q_{ff} is connected to a primary winding 58 of a two winding magnetic element indicated at 53. Drain 56 of switch Q_{ff} is coupled to ground 57. While many types of switches can be used at Q_{ff}, the preferred embodiment encompasses a Mosfet type transistor. The diode inherent in the Mosfet transistor is shown as D_{ff} coupled from drain 56 to source 54 of transistor Q_{ff}. The other side of the primary winding 58 of the magnetic element 53 is connected to positive DC voltage Vin as shown at 59. The switch Q_{ff} is bridged by a capacitance C_r connected between its source 54 and drain, 56. Capacitance C_r forms a resonant circuit with the other reactive components.

The inverter is preferably connected to piezoelectric element 12 and the pair of discrete bidirectional switchs through the secondary winding 61 of the two winding magnetic element 53. The turns ratio between the primary winding 58 and the secondary winding 61 is shown as being 1:n where n in one preferred embodiment is in a range between 2 and 25.

One side of winding 61 is preferably connected to ground at 62. The other side is connected to the common electrode 17 of the motor 11. The other electrodes of the motor 11, i.e. electrode pairs 13 and 14 are connected to high frequency switches such as switches M_{S1} and M_{S2}, in the manner described above with respect to Fig. 4.

The operation of the combination of the discrete inverter and the discrete bi-directional switch, in combination, is more clearly understood with reference to the schematic of Fig. 6. That schematic shows one of the switches open and the other closed with all secondary components (including the closed lines) being reflected to the primary. The inductance of the two element magnetic unit 53 is shown as L_{lkg}, i.e. the leakage inductance of the magnetic element 53. The piezoelectric element 12 of the motor 11 is represented by the impedance Z_M which is mainly capacitive in the nature at the mechanical resonance frequency. It is shown as being divided by n^2 when reflected into the primary of magnetic unit 53.

A square wave voltage V_{sq} is shown applied to the gate of switch Q_{ff} whose drain is connected ground and whose source is connected to inductor L_m and to motor (impedance) element Z_M. Diode D_{ff} is shown as is resonance capacitance C_r, both bridging switch Q_{ff}. Capacitance Cr is in series with and resonates with the inductance Lm bridged by the leakage inductance L_{lkg} in series with the reactance Z_M/n^2.

While a square wave operating voltage V_{sg} is shown; it should be understood that the operating voltage can assume other forms as known in the art within the scope of the invention.

When the switch Q_{ff} is conducting, as shown in Fig. 7, energy is delivered to the motor in a resonant manner in the two half cycles. When the high frequency switch Q_{ff} is conducting, energy is transferred from the voltage source to the motor and energy is also stored in inductance L_m. A resonance circuit is formed between the leakage inductor L_{kj} and the motor impedance Z_m. Hence the voltage wave form fed to the motor is sinusoidal.

During a non conducting period of the switch Q_{ff}, as shown is Fig. 8, the energy stored in the inductance L_m is transferred to the motor. Notice that the voltage to the motor now is of opposite polarity than the voltage that was applied during the conducting stage of switch Q_{ff}. Reactive element L_m, bridged by the series connection of L_{kj} and Z_m/n^2 forms a resonant circuit that can shape the voltage across the motor to be sinusoidal by properly choosing the circuit parameters. Preferably, this circuit is resonant at the mechanical resonance frequency.

Note that, when the wave form across the switch is sinusoidal, the switch operates under "soft" switching conditions. In other words if switch Q_{ff} turns off after voltage across it reduces to zero, the switch is turned on under zero voltage conditions. Then, when the switch Q_{ff} is turned off, the voltage will rise across it relatively slowly due to the action of capacitor C_r. Hence zero voltage switching at turn off is achieved.

Thus the circuit of Fig. 5, according to this preferred embodiment of the invention, may have one or more of a number of advantages, for example:

i) a single switch is used for implementing the inverter section,

ii) all signal drives are referred to one ground,

iii) by choosing the proper turns ratio the motor voltage can be made high even if V_{in} is a low DC voltage,

iv) the motor signals are of low harmonic content, and in addition

v) the total part count is very low, i.e. the inverter section is based on a single transistor and the discrete bidirectional switch has only two transistors.

Further the embodiment of Fig 5 is suitable for relatively low power levels.

As can be well understood, the exact design details for such circuitry is a function of the exact physical and electrical parameters. However, the design can be optimized for the particular characteristics of piezoelectric element utilizing design programs such as SPICE or the like. Once such a design is achieved, the components (including the non-ideal transformers used in the designs) may be designed and produced using methods well known in the art or magnetic component design.

Another preferred embodiment of the invention is shown in Fig. 9, in which the discrete inverter is of a push-pull configuration. The push-pull configuration is suitable for higher power levels then is the forward flyback inverter. In the push-pull arrangement of the inverter shown in Fig 9, two switches Q_{p1} and Q_{p2} operate on the load in a push-pull manner through a resonant network. The resonant network comprises the inductance of a transformer TR whose secondary is bridged by capacitor C_{pp}. Current from the DC voltage V_{in} is applied to primary 66 of transformer TR through series inductor L_{sp}. The input to the transformer is to the middle of the primary windings 66 as shown in Fig 9. In a preferred embodiment of the invention, the two switches Q_{p1} and Q_{p2} are Mosfet transistors.

One side of primary 66, goes to the source 67 of transistor Q_{p1}. Drain 68 of transistor Q_{p1} is coupled to ground at 69. The other side of the primary winding 66 of transformer TR is coupled to source 72 of switch Q. Drain 73 of transistor switch Q_{p2} is coupled to ground. Both transistors Q_{p1} and Q_{p2} are shown as having square wave control voltages applied to their gates 74 and 76 respectively, for converting the DC voltage input to an AC voltage at the resonant frequency. Control voltages with other waveforms could be used within the scope of the invention. The secondary winding n1 of transformer TR, has one side 77 connected to ground and the other side 78 connected to common electrode 17 of motor 11. When the parameters of the circuit are properly chosen the signal fed to the motor 11 will be of a sinusoidal shape with low harmonic distortion.

The major benefit of the push-pull embodiment over the forward-flyback embodiment is the capability to handle higher power levels. Furthermore, by slight modification, the output of voltage of the push-pull embodiment can be further controlled as is illustrated in Fig 11. Here an additional high frequency switch Q_{buck} and diode D_{buck} have been added. These elements together with inductor L_{sp} form a "down" or "buck" inverter. This type of inverter is controlled by the duty cycle D_{on} of Q_{buck}. Assuming a sinusoidal wave form, the voltage at point "A" in Fig. 11 will be as shown in Fig 12. The peak value V_{pk} of this wave form will be related to the motor voltage by the equation:

$V_{PK} = V_{motor}/n$.

At steady state, the average voltage across the inductor L_{sp} will be zero and hence the average of V_{pk} must be equal to the voltage at point "B" in Fig. 10 which is equal to $V_{in}*D_{on}$. Hence:

$V_{PK} = nV_{in}*D_{on}$.

Consequently from these equations:

$V_{motor} = n*V_{in}*D_{on}$.

Hence the motor voltage can be controlled by varying D_{on} of Q_{buck}. This feature is particularly applicable when variable motor voltages, are called for such as for varying the speed of the motor.

The preferred embodiments have been described in relation to a piezoelectric motor having a common electrode on one face of a piezoelectric ceramic and two pairs of electrodes on the other face. However, the motor may also operate more of fewer electrodes and with different configuration. Further it can be adapted to other configurations of piezoelectric motors.

Furthermore, a bipolar switch in accordance a preferred embodiment of the invention may be used for various other applications. In fact many AC loads may be switched using such a bipolar switch. In general, it is difficult to switch an AC load with a single MOS transistor. In accordance with a preferred embodiment of the invention, a switch, such as one half of the circuit shown in Fig. 4, may be used to switch a capacitive AC load, using a single transistor. Furthermore, if the load is not capacitive a large (compared to the admitance of the load) capacitor may be placed in series with the load. For AC purposes (i.e., when the switch is closed) the capacitor has negligible effect. However, when the switch is open, the voltage across the capacitor will rise to the peak of the AC voltage switching the load off, as described above.

Various modifications will be apparent to and will be readily available to those skilled in the art without departing from the scope and spirit of the invention. Accordingly it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein but rather that the claims be broadly construed. It should be understood that the verbs "comprise" and "include" and their conjugations, when used in the claims, mean "including, but not necessarily limited to."

CLAIMS

1. A micromotor comprising:

a piezoelectric element including a common electrode and a plurality of other electrodes formed thereon and including at least a first and a second electrode group, each group including at least one electrode, wherein the piezoelectric element causes motion in a first direction when a voltage is applied between the first electrode group and the common electrode and wherein the piezoelectric element causes motion in a second direction when a voltage is applied between the second electrode group and the common electrode;

an voltage source that electrifies the common electrode; and

at least two switches separately connected between the first and second electrode groups and a low voltage, said switches being activatable to connect one of said first and second electrode groups to the low voltage to cause selective motion in the first or second directions.

2. A micromotor according to claim 1 wherein the low voltage is substantially ground.

3. A micromotor according to claim 1 or claim 2 wherein the applied voltage is an AC voltage.

4. A micromotor according to any of the preceding claims wherein the piezoelectric element comprises a rectangular piezoelectric plate having first and second faces wherein the common electrode is formed on the first face and the first and second groups of electrodes are formed on the second face.

5. A micromotor according to claim 4 wherein the first and second groups of electrodes each comprises two electrodes situated in opposite quadrants of the second face.

6. A micromotor according to any of the preceding claims wherein the micromotor comprises a motive surface and wherein motion is induced in a surface of a workpiece pressed against the motive surface when the piezoelectric element is electrified as aforesaid.

7. A micromotor comprising:

an ultrasonically vibrating element; and

a drive circuit comprising:

an oscillating voltage source connected to and electrifying at least one electrode of said ultrasonically vibrating element to cause a mechanical displacement of a portion thereof; and

a discrete switch arrangement attached to at least one additional electrode of said ultrasonically vibrating element to which said oscillating voltage is not connected which switch arrangement selects the direction of said displacement.

8. A micromotor according to claim 7 wherein the ultrasonically vibrating element comprises a piezoelectric element.

9. A micromotor according to claim 7 or claim 8, wherein:

the at least one additional electrode comprises a plurality of electrodes applied to a first face of said vibrating element; and

the at least one electrode comprises a common electrode applied to a second face of said element.

10. A micromotor according to claim 9 wherein the discrete switch arrangement selectively applies voltage between a first group of said plurality of electrodes and said common electrode to cause displacement in a first direction, said first group including at least one electrode.

11. A micromotor according to claim 10, wherein the discrete switch arrangement selectively applies voltage between a second group of said plurality of electrodes and said common electrode to cause displacement in a second direction, said second group comprising at least one electrode.

12. A micromotor according to any of the preceding claims wherein said discrete switching arrangement comprises a pair of switches connected to apply voltages across said element to drive current through said element, and controls for selectively operating said switches to select the direction of said displacement.

13. A micromotor according to claim 12 wherein said switches of said discrete switching arrangement are solid state switches.

14. A micromotor according to claim 12 or 13 wherein said switches of said discrete switching arrangement comprise transistorized switches.

15. A micromotor according to claim 14 wherein said switches of said discrete switching arrangement are Mosfet transistors.

16. A micromotor according to claim 11 wherein said discrete switch arrangement comprises:

a first Mosfet connected between a first voltage and said first group of electrodes;

a second Mosfet connected between said first voltage and said second group of electrodes, said common electrode being connected to a second voltage, and

a control that selectively operates said Mosfet switches to selectively apply said first voltage to the first electrode group or to said second electrode group.

17. A micromotor according to claim 16 including a source of control voltages selectively applied to the gates of said first and second Mosfet transistors for selectively switching said first or said second Mosfet transistors from the non conducting state to the conducting state.

18. A micromotor according to claim 16 or claim 17 and including a pair of diodes, one of which is connected across each said Mosfet transistor.

19. A micromotor according to claim 18 wherein the diodes are connected such that they conduct DC current toward the micromotor.

20. A micromotor according to any of claims 17-19 wherein, when the transistor is off, one end of the Mosfet is at a DC voltage equal to the peak of the oscillating voltage and the oscillating voltage is impressed across the Mosfet transistor, such that the voltage across the transistor is substantially unipolar.

21. A micromotor according to any of the preceding claims wherein said source comprises an inverter.

22. A micromotor according to claim 21 wherein the inverter is a forward-flyback inverter.

23. A micromotor according to claim 22 wherein said forward-flyback inverter comprises:

a magnetic element having a primary winding and a secondary winding, said primary winding being connected between a first inverter voltage and one side of an inverter operating switch, the other side of said inverter operating switch connected to a second inverter voltage so that when said inverter operating switch is in the conductive stage, current flows through said primary and when said inverter operates switch is in a non conductive state substantially no current flows through said primary; and

a control voltage source which selectively turns said inverter operating switches on or off, the secondary of said magnetic element being connected to said discrete switching arrangement.

24. A micromotor according to claim 23 wherein said inverter operating switches are solid state switches.

25. A micromotor according to claim 23 wherein said inverter operating switches are transistorized switches.

26. A micromotor according to claim 23 wherein said inverter operating switches are Mosfet transistors, and comprising:

circuitry that causes said inverter output to resonate at substantially the mechanical resonant frequency of said piezoelectric element.

27. A micromotor according to claim 26 wherein said circuitry that causes said inverter output to resonate at substantially the mechanical resonant frequency of the piezoelectric comprises a capacitor bridging said switch and in series with the primary of the magnetic element, said capacitor operating in conjunction with the capacitance of said ultrasonically vibrating motor to turn said magnetic element to resonate at substantially the mechanical resonant frequency of the motor.

28. A micromotor according to claim 21 wherein said inverter is a push-pull inverter.

29. A micromotor according to claim 28 wherein said push-pull inverter comprises a transformer, having a primary and a secondary;

a series inductor connecting a first inverter input to a mid part of the primary of said transformer,

the secondary of said transformer connected to said discrete switching arrangement and one side of the primary of said transformer being connected through a first push-pull inverter switch to a second inverter input,

the other side of said primary of said transformer being connected through a second push-pull inverter switch to said second input.

30. A micromotor according to claim 29 wherein said first and second push-pull switches are solid states switches.

31. A micrometer according to claim 30 wherein said first and second push-pull inverter switches are transistorized switches.

32. A micromotor according to claim 30 wherein said first and second push-pull inverter switches are Mosfet type switches.

33. A micromotor according to any of claims 29-31 wherein the capacitance of said ultrasonic motor and the inductances of the series inductance and of said transformer match the electrical circuit to the mechanical resonance of said piezoelectric element.

34. A micromotor according to claim 33 wherein the first and the second push-pull inverter switches are each selectively operated by control voltages.

35. A micromotor according to claim 34 wherein the control voltages are square wave voltages.

36. A micrometer according to any of claims 29-35 wherein said push-pull inverter includes a buck section for controlling the amplitude of the voltage connected to said primary of said transformer.

37. A micromotor according to claim 36 wherein said buck section includes:

a series buck section switch connected between the first input of the inverter and the series inductor;

a diode connected between an output of the buck section switch and said second input of the inverter and,

a control voltage operative to cause the buck section switch to conduct.

38. A micromotor according to any of claims 29-37 wherein the second input is ground.

39. A micromotor according to any of claims 29-38 wherein the first input is electrified with a DC voltage.

40. A method of supplying switchable AC power to a load comprising:

connecting a first terminal of an AC power source to one side of the load;

connected a Mosfet transistor between a second terminal of the AC power source and the other side of the load; and

selectively supplying power to the load by applying a voltage between a gate of the Mosfet and the second AC terminal.

41. A method according to claim 40 and including connecting a diode across the Mosfet transistor.

42. A method according to claim 41 wherein the diode is connected such that it conducts current between the second terminal and the other side of the load.

43. A method according to any of claims 40-42 and including placing a capacitor in series with the load.

44. A method according to claim 43 wherein the load does not comprise a DC blocking capacitor.

45. A method according to any of claims 40-44 wherein, when the transistor is off, one end of the Mosfet is at a DC voltage equal to the peak voltage of the AC source and AC voltage of the AC source is impressed across the Mosfet transistor, such that the voltage across transistor is substantially unipolar.

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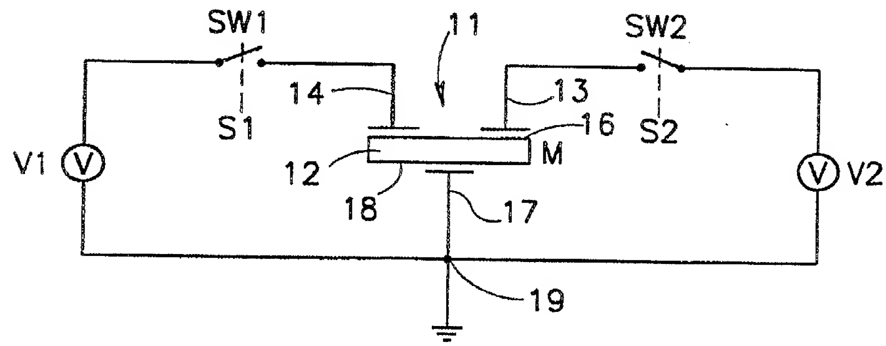


FIG.1A
PRIOR ART

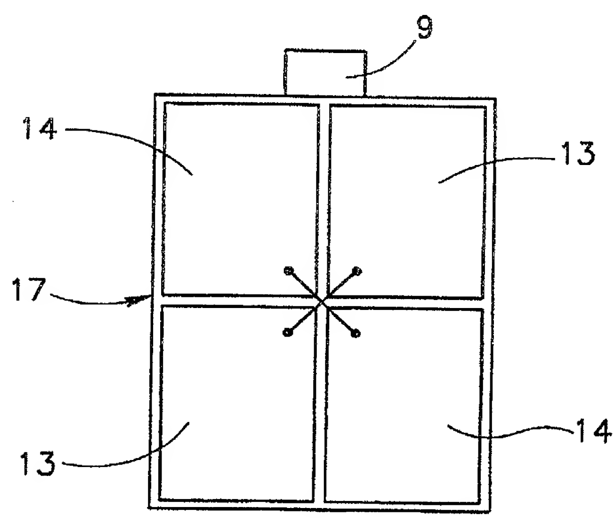


FIG.1B

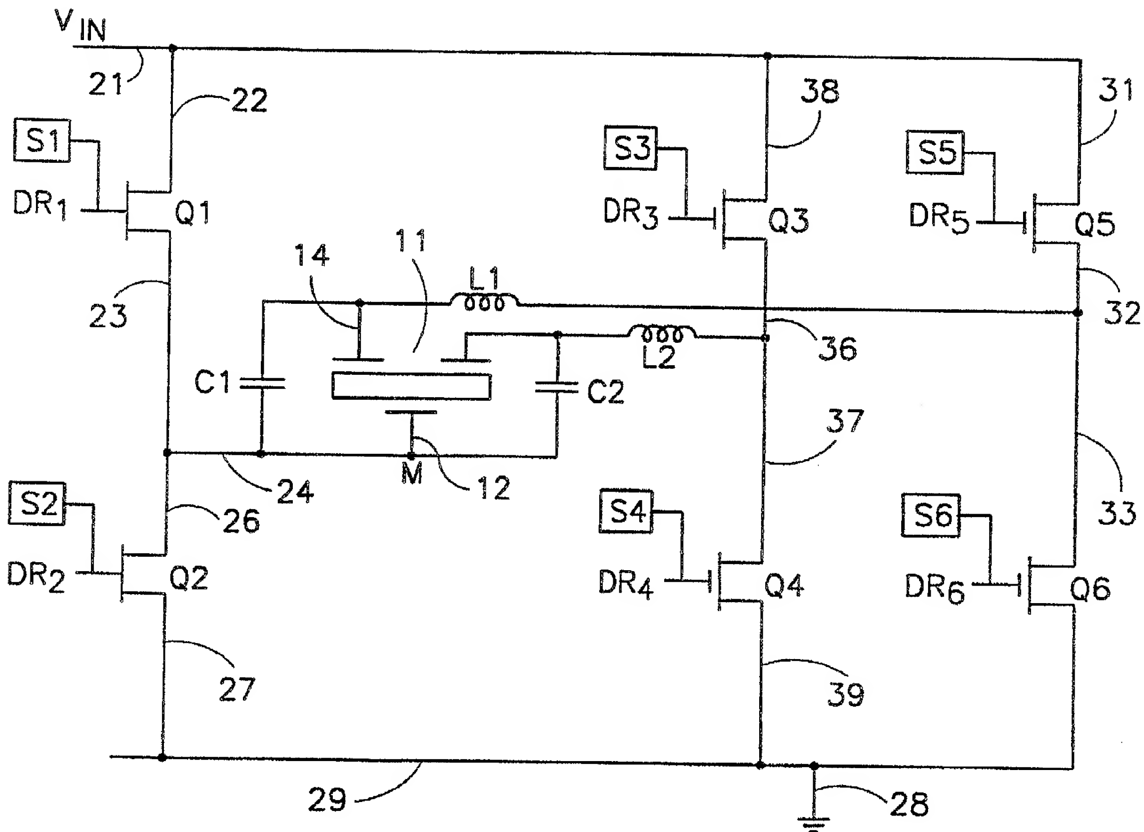
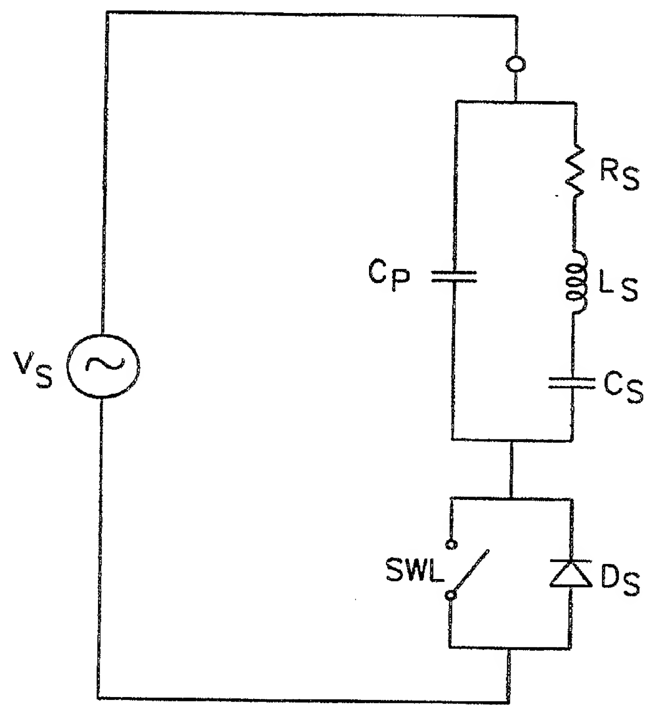
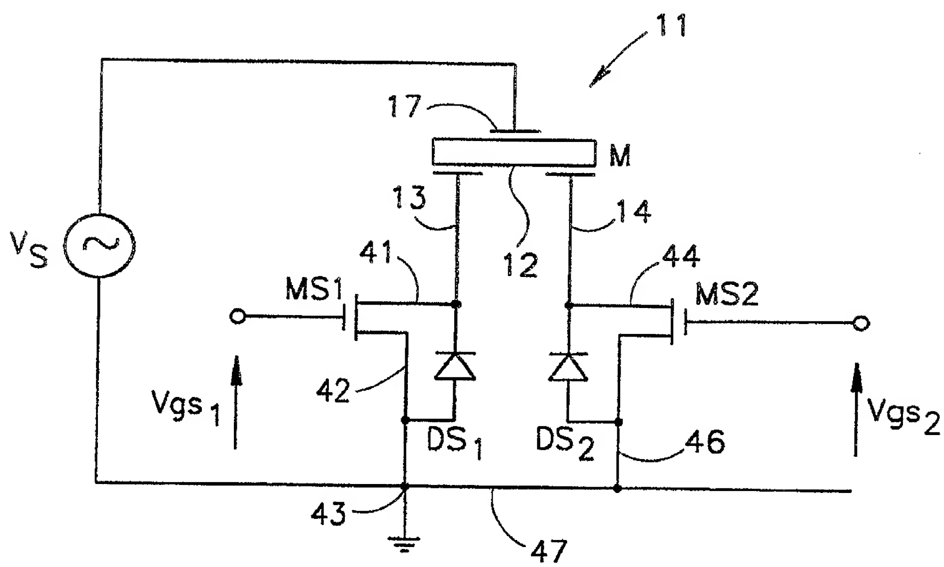


FIG.2
PRIOR ART



V_S
C_P
R_S
L_S
C_S
SWL
D_S

FIG.3



11
17
M
13
14
12
V_S
41
44
MS1
MS2
Vgs_1
Vgs_2
42
DS_1
DS_2
46
43
47

FIG.4

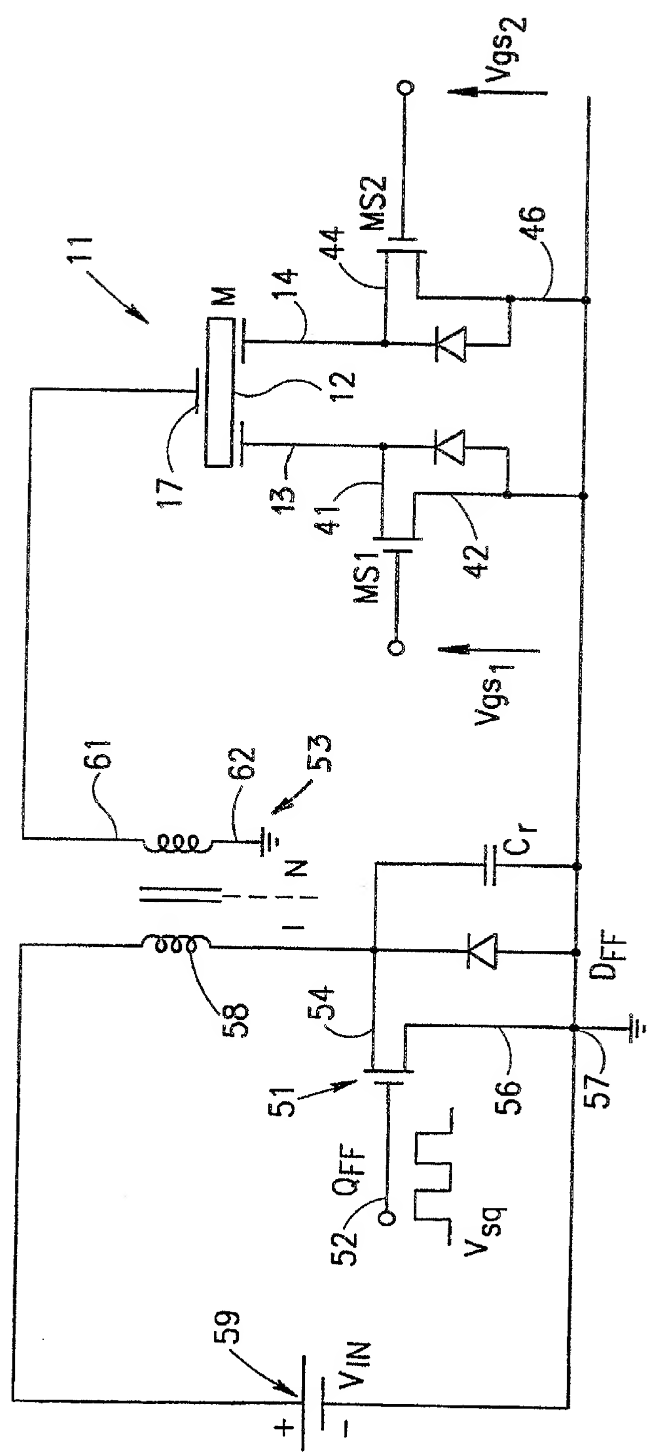

11
M
12
13
14
17
41
42
44
46
MS1
MS2
Vgs1
Vgs2
61
62
53
N
Cr
58
54
DFF
51
56
57
QFF
52
Vsq
59
VIN
+
-

FIG.5

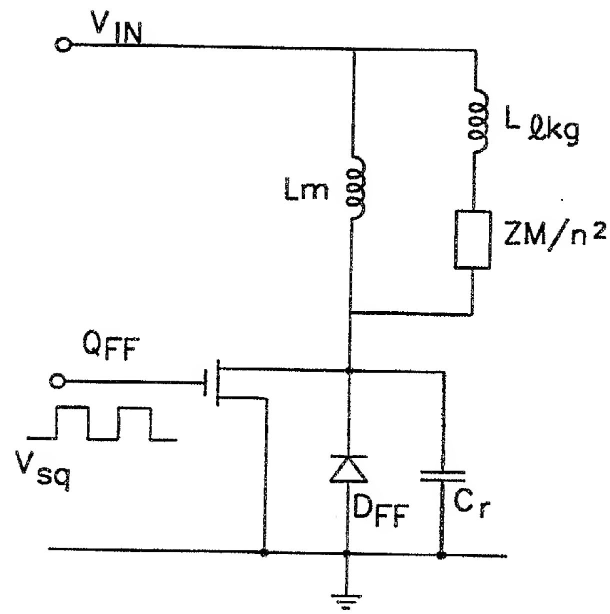


FIG.6

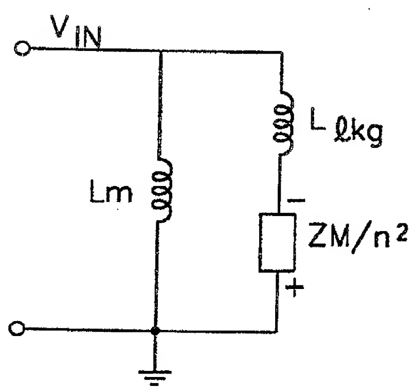


FIG.7

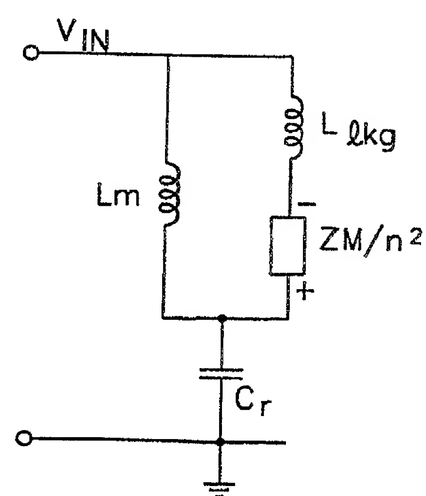


FIG.8

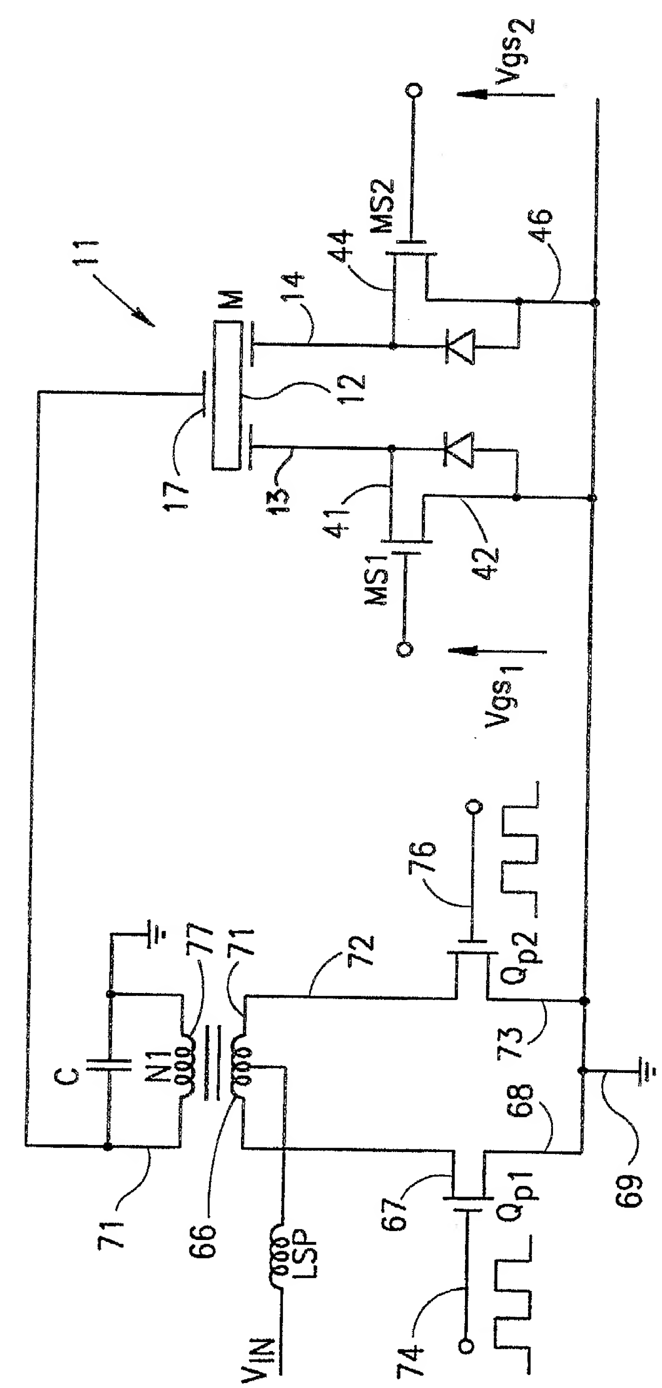

11
M
12
14
13
17
41
42
44
46
MS1
MS2
Vgs1
Vgs2
C
N1
77
71
72
73
76
Qp1
Qp2
66
67
68
69
74
LSP
VIN

FIG.9

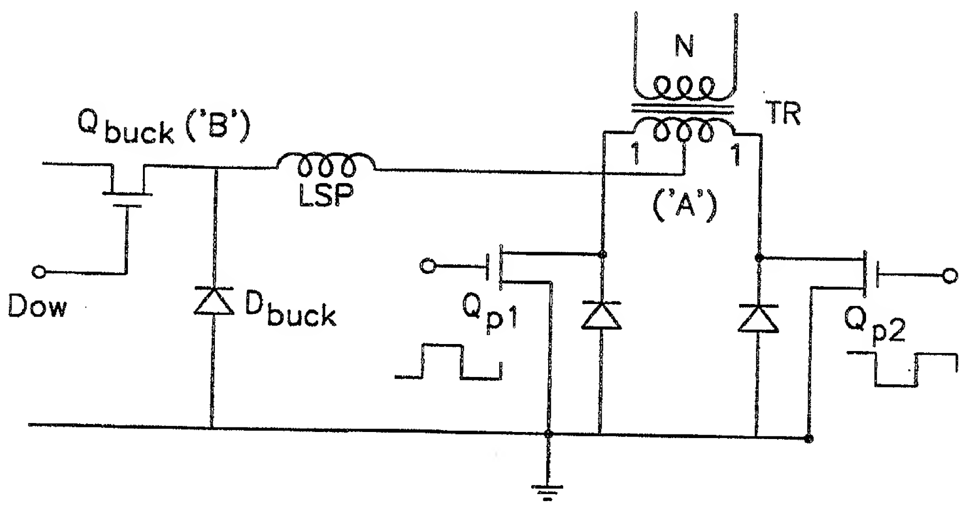


FIG. 10

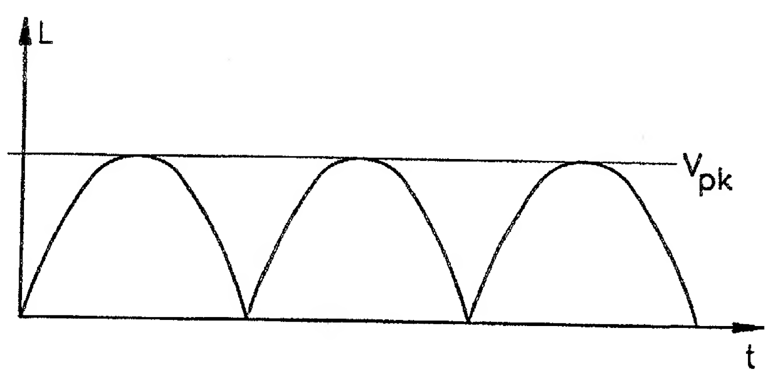


FIG. 11

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INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/IL 98/00519

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01L41/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 712 170 A (NANOMOTION LTD) 15 May 1996 see figure 7	1

[ ] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 1999	23/06/1999

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/IL 98/00519

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0712170 A	15-05-1996	US 5640063 A	17-06-1997

US 0983037405P1

Creation date: 10-02-2003
Indexing Officer: EGEDLU - ESKINDER GEDLU
Team: CENTRALSCANPRINT
Dossier: 09830374

Legal Date: 04-11-2002

No.	Doccode	Number of pages
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2	C.AD	1

Total number of pages: 3

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